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(54) **HYDRAULIC PUMP CONTROLLER**

HYDRAULISCHER PUMPENREGLER

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(73) Proprietor: **HITACHI CONSTRUCTION MACHINERY CO., LTD.**
Bunkyo-ku, Tokyo 112-0004 (JP)

(72) Inventors:
- **HIRATA, Toichi**
  Ibaraki 300-12 (JP)
- **SUGIYAMA, Genroku**
  Inashiki-gun, Ibaraki 300-04 (JP)
- **WATANABE, Hiroshi**
  Ushiku-shi, Ibaraki 300-12 (JP)
- **YOSHINAGA, Shigehiro**
  Niihari-gun, Ibaraki 315 (JP)

(74) Representative: **Beetz & Partner Patentanwälte**
Steinsdorfstrasse 10
80538 München (DE)

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Description

TECHNICAL FIELD

[0001] The present invention relates to a hydraulic pump control system for use with a hydraulic drive system of hydraulic working machines such as hydraulic excavators, and more particularly to a hydraulic pump control system which carries out flow rate control of a hydraulic pump for driving a plurality of hydraulic actuators. Such a system is kown from EP-A-0 537 369.

BACKGROUND ART

[0002] A hydraulic working machine such as a hydraulic excavator is equipped with a hydraulic drive system including a plurality of hydraulic actuators, a hydraulic pump, etc., and conducts various required operations while driving the plurality of hydraulic actuators by the hydraulic pump. The hydraulic drive system generally used comprises a variable displacement hydraulic pump, a plurality of hydraulic actuators driven by the hydraulic pump, a plurality of flow control valves of the center bypass type for controlling the driving of the hydraulic actuators, and a center bypass line connecting the center bypasses of the flow control valves in series. As disclosed in JP, A, 1-25921, such a hydraulic drive system also comprises a flow resisting mean, e.g., a fixed throttle, disposed downstream of the center bypass line for generating a negative control pressure in the center bypass line, a pressure sensor for detecting the negative control pressure generated in the center bypass line, a controller for calculating, based on the detected value of the pressure sensor, the target displacement volume of the hydraulic pump (i.e., the tilting amount of a swash plate) in accordance with a preset characteristic and then outputting an electric signal corresponding to the calculated value, and a regulator driven by the electric signal for controlling the displacement volume of the hydraulic pump.

[0003] The center bypass of each of the flow control valves is fully opened when the associated flow control valve is in a neutral position, and is restricted gradually as the valve is shifted from the neutral position. When all the flow control valves are in neutral positions, i.e., any of the hydraulic actuators is not driven, a hydraulic fluid delivered from the hydraulic pump is passed at a full flow rate through the center bypass line, and the negative control pressure detected by the pressure sensor is maximized. The controller calculates the minimum target displacement volume in accordance with the preset characteristic, and the hydraulic pump is controlled so that the displacement volume (i.e., the delivery rate) thereof is minimized. In an attempt to drive one hydraulic actuator, for example, when the corresponding flow control valve is operated, the center bypass of the operated valve is restricted to reduce the flow rate passing through the center bypass line, and the negative control pressure detected by the pressure sensor is also reduced. Therefore, the target displacement volume calculated by the controller is increased in accordance with the preset characteristic, whereupon the hydraulic pump increases the target displacement volume and delivers the hydraulic fluid at a flow rate enough to drive the hydraulic actuator.

DISCLOSURE OF THE INVENTION

[0004] In the conventional hydraulic pump control system described above, irrespective of the type of hydraulic actuator to be driven, the displacement volume of the hydraulic pump is uniquely determined by the controller in accordance with the preset characteristic for the negative control pressure generated depending on the amount by which any of the hydraulic actuator is operated, i.e., the control input for operating it. However, preferable driving speeds of the hydraulic actuators are different one by one, and control levers are mostly manipulated over their full strokes in usual operations.

[0005] Taking a hydraulic excavator as an example, preferable driving speeds of the hydraulic actuators are as follows. It is desired for a boom cylinder to have a large maximum driving speed to achieve high working efficiency. Since a swing motor is of great inertia and poses a difficulty in precisely stopping the same at the intended position, it desirably has a small maximum driving speed. Since a bucket cylinder is of small size and frequently strikes against the stroke end when driven, it desirably has a small maximum driving speed in order to prevent shocks, deterioration in durability, useless pressure relief, etc. Further, an arm cylinder is of smaller size than the boom cylinder and suffers the similar problem to that of the bucket cylinder, but it is closely related to operation of the boom cylinder in many cases during the work. Therefore, the arm cylinder desirably has a large maximum driving speed as with the boom cylinder.

[0006] For the purpose of efficiently carrying out the work, the characteristic determined by the controller is usually selected such that the boom cylinder, for example, can be driven at a satisfactory speed. Accordingly, when a swing control lever or a bucket control lever is manipulated over its full stroke, the swing motor or the bucket cylinder is driven at an excessive speed, resulting in drawbacks below. For the swing motor, a difficulty is caused in precisely stopping the motor at the intended position, durability of the motor itself and speed reducing gears is reduced, and noise is increased. For the bucket cylinder, shocks and useless pressure relief are caused whenever it strikes against the stroke end, and hence durability of the cylinder is deteriorated.

[0007] Those problems are encountered not only in hydraulic excavators taken above as an example, but also in various hydraulic working machines, other than hydraulic excavators, which include a plurality of hydraulic actuators.

[0008] An object of the present invention is to solve the above-mentioned problems in the prior art, and to provide a hydraulic pump control system which can suppress unwanted speed increases of hydraulic actuators.

[0009] To achieve the above object, according to the present invention, there is provided a hydraulic pump control system for use with a hydraulic drive system comprising a variable displacement hydraulic pump, a plurality of hydraulic actuators driven by the hydraulic pump, a plurality of flow control valves of the center bypass type for controlling the driving of the hydraulic actuators, and a center bypass line connecting the center bypasses of the flow control valves in series, the hydraulic pump control system controlling a displacement volume of the hydraulic pump by using a negative control pressure generated by flow resisting means which is disposed downstream of the center bypass line, the hydraulic pump control system comprising pressure detecting means for detecting the negative control pressure generated in the center bypass line, first target displacement volume calculating means for calculating, based on a detected value of the pressure detecting means, a first target displacement volume of the hydraulic pump in accordance with a preset first characteristic, first control input detecting means for detecting a control input for operating at least one of the plurality of hydraulic actuators, maximum target displacement volume limiting means for limiting, depending on the detected value of the first control input detecting means, a maximum value of the first target displacement volume calculated by the first target displacement volume calculating means based on the detected value of the pressure detecting means, and providing a target displacement volume to be output, and a regulator for controlling the displacement volume of the hydraulic pump in accordance with the target displacement volume to be output.

[0010] In the hydraulic pump control system thus arranged, when one or more corresponding control means are manipulated for driving one or more hydraulic actuators, the detected value of the pressure detecting means for detecting the negative control pressure is changed and the first target displacement volume calculating means calculates the first target displacement volume corresponding to the resulting detected value in accordance with the preset first characteristic. At the same time, the first control input detecting means detects the control input for operating the at least one hydraulic actuator, and the maximum target displacement volume limiting means limits, depending on the detected value of the first control input detecting means, the maximum value of the first target displacement volume calculated by the first target displacement volume calculating means and provides the target displacement volume to be output. In this respect, when the hydraulic actuator to be driven is the at least one hydraulic actuator, the detected value of the first control input detecting means is output as a value depending on the control input and the maximum value of the first target displacement volume limited by the maximum target displacement volume limiting means is given as a value corresponding to the resulting detected value. For example, when a control lever is manipulated over its full stroke, the detected value of the first control input detecting means is maximized and the maximum value of the first target displacement volume limited by the maximum target displacement volume limiting means is also maximized. Therefore, the displacement volume of the hydraulic pump is controlled so as to maximize the maximum target displacement volume, making it possible to increase the maximum driving speed of the at least one hydraulic actuator.

[0011] On the other hand, when the hydraulic actuator to be driven is other one than the at least one hydraulic actuator, the detected value of the first control input detecting means is 0 and the maximum value of the first target displacement volume is limited by the maximum target displacement volume limiting means so as to be minimized. Then, the first target displacement volume of the thus-minimized maximum value is used as the target displacement volume to be output for controlling the hydraulic pump. It is therefore possible to prevent an unwanted speed increase of the other hydraulic actuator than the at least one hydraulic actuator.

[0012] In the above hydraulic pump control system, preferably, the maximum target displacement volume limiting means comprises second target displacement volume calculating means for calculating, based on the detected value of the first control input detecting means, a second target displacement volume of the hydraulic pump in accordance with a preset third characteristic different from the first characteristic, and smaller value selecting means for selecting smaller one of the first and second target displacement volumes as the target displacement volume to be output.

[0013] In this case, preferably, the first characteristic is such that the first target displacement volume increases from a predetermined minimum value to a predetermined maximum value as the detected value of the pressure detecting means is reduced, and the second characteristic is such that the second target displacement volume increases from a predetermined minimum value to a predetermined maximum value as the detected value of the first control input detecting means is increased, the predetermined minimum value of the second characteristic being smaller than the predetermined maximum value of the first characteristic. In this connection, it is desired that the predetermined maximum value of the second characteristic is equal to the predetermined maximum value of the first characteristic.

[0014] In the above hydraulic pump control system, preferably, the system further comprises second control input detecting means for detecting a control input for operating other one of the plurality of hydraulic actuators or a control input in a different direction from the control input for operating the at least one hydraulic actuator, the maximum target displacement volume limiting

means further comprises third target displacement volume calculating means for calculating, based on the detected value of the second control input detecting means, a third target displacement volume of the hydraulic pump in accordance with a preset third characteristic different from both the first and second characteristics, and the smaller value selecting means selects a minimum value of the first, second and third target displacement volumes as the target displacement volume to be output.

[0015] In this case, preferably, the third characteristic is such that the third target displacement volume reduces from a predetermined maximum value to a predetermined minimum value as the detected value of the second control input detecting means is increased.

[0016] In the above hydraulic pump control system, preferably, the at least one actuator is an actuator of which desired maximum driving speed is relatively large. As one example, the actuator of which desired maximum driving speed is relatively large is a boom cylinder for operating a boom of a hydraulic excavator. Alternatively, the actuator of which desired maximum driving speed is relatively large is an arm cylinder for operating an arm of a hydraulic excavator.

[0017] When one or more corresponding control means are manipulated for driving one or more hydraulic actuators, the detected value of negative control pressure detecting means is changed and the tilting amount corresponding to the resulting detected value is extracted in accordance with one preset characteristic. On the other hand, when specific control means is manipulated, the amount by which the specific control means has been manipulated, i.e., the control input from the specific control means, is detected by the control input detecting means and the tilting amount corresponding to the resulting detected value is extracted in accordance with another preset characteristic. All the extracted tilting amounts are compared with one another in minimum value selecting means which outputs a minimum value among them. Regulator driving means drives the regulator in accordance with the selected minimum value for tilting a swash plate of the hydraulic pump. By setting the characteristics appropriately, the speed of a specific hydraulic actuator is suppressed when it is driven solely.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Fig. 1 is a hydraulic circuit diagram of a hydraulic pump control system for a hydraulic drive system according to a first embodiment of the present invention.

[0019] Fig. 2 is a view showing detailed construction of a control lever unit.

[0020] Fig. 3 is a side view of a hydraulic excavator on which the hydraulic drive system for use with the present invention is equipped.

[0021] Fig. 4 is a block diagram for explaining functions of a controller shown in Fig. 1.

[0022] Fig. 5 is a graph for explaining the function of limiting a maximum value of the target tilting amount in the block diagram of Fig. 4.

[0023] Fig. 6 is a hydraulic circuit diagram of a hydraulic pump control system for a hydraulic drive system according to a second embodiment of the present invention.

[0024] Fig. 7 is a block diagram for explaining functions of a controller shown in Fig. 6.

BEST MODE FOR CARRYING OUT THE INVENTION

[0025] Embodiments of the present invention will be described below with reference to the drawings. In the embodiments, the present invention is applied to a hydraulic drive system of hydraulic excavators.

[0026] In Fig. 1, a hydraulic drive system for carrying out the first embodiment of the present invention comprises a variable displacement hydraulic pump 1 having a displacement volume varying mechanism (hereinafter represented by a swash plate) la, a plurality of hydraulic actuators driven by the hydraulic pump 1, i.e., a boom cylinder 6, an arm cylinder 7, a bucket cylinder 8 and a swing motor 9, a plurality of flow control valves 10, 11, 12, 13 of the center bypass type for controlling the driving of the hydraulic actuators, and a center bypass line 5 connecting the center bypasses of the flow control valves in series. The center bypass line 5 has an upstream end connected to the hydraulic pump 1 and a downstream end connected to a reservoir. Also, input ports of the flow control valves 10 to 13 are connected to the hydraulic pump 1 in parallel via a bypass line 14.

[0027] The flow control valves 10 to 13 are of hydraulically pilot-operated valves and are operated with pilot pressures A to H output from control lever units 62, 63 shown in Fig. 2. More specifically, the control lever unit 62 comprises boom pilot valves 62a, 62b, bucket pilot valves 62c, 62d, and a common control lever 62e which can be manipulated in any of four crucial directions for selectively operating those pilot valves. The pilot valves 62a, 62b; 62c, 62d are each operated depending on the amount by which the control lever 62e is manipulated in corresponding one of the four crucial directions, i.e., on the corresponding control input, thereby delivering the pilot pressures A, B, C, D in accordance with the respective control inputs. The control lever unit 63 comprises arm pilot valves 63a, 63b, swing pilot valves 63c, 63d, and a common control lever 63e which can be manipulated in any of four crucial directions for selectively operating those pilot valves. The pilot valves 63a, 63b; 63c, 63d are each operated depending on the amount by which the control lever 63e is manipulated in corresponding one of the four crucial directions, i.e., on the corresponding control input, thereby delivering the pilot pressures E, F, G, H in accordance with the respective control inputs.

[0028] The hydraulic excavator on which the above-described hydraulic drive system is equipped compris-

es, as shown in Fig. 3, an undercarriage 100, an upper structure 101 and a front attachment 103 for working. The front attachment 103 for working comprises a boom 104, an arm 105 and a bucket 106. The boom 104 is angularly moved in the vertical direction by the boom cylinder 6, the arm 105 is angularly moved back and forth by the arm cylinder 7, the bucket 106 is angularly moved back and forth as well as in the vertical direction by the bucket cylinder 8, and the upper structure 101 is swung by the swing motor 9.

[0029] In the hydraulic excavator, preferable driving speeds of the hydraulic actuators 6 to 9 are different one by one. More specifically, it is desired for the boom cylinder 6 to have a large maximum driving speed to achieve high working efficiency. Since the swing motor 9 is of great inertia and poses a difficulty in precisely stopping the same at the intended position, it desirably has a small maximum driving speed. Since the bucket cylinder 8 is of small size and frequently strikes against the stroke end when driven, it desirably has a small maximum driving speed in order to prevent shocks, deterioration in durability, useless pressure relief, etc. Further, the arm cylinder 7 is of smaller size than the boom cylinder 6 and suffers the similar problem to that of the bucket cylinder, but it is closely related to operation of the boom cylinder in many cases during the work. Therefore, the arm cylinder 7 desirably has a large maximum driving speed as with the boom cylinder 6.

[0030] A hydraulic pump control system of this embodiment is employed for use with the hydraulic drive system described above. The hydraulic pump control system of this embodiment comprises a regulator 19 for controlling the tilting amount of the swash plate la of the hydraulic pump 1 (i.e., the displacement volume of the hydraulic pump 1), a fixed throttle 20 disposed downstream of the center bypass line 5 for generating a negative control pressure in the center bypass line 5, a pressure sensor 21 for detecting the negative control pressure generated in the center bypass line 5, a pressure sensor 22 for detecting the pilot pressure A acting on the boom-up side of the flow control valve 10, a pressure sensor 23 for detecting the pilot pressure E acting on the arm crowding side of the flow control valve 11, a controller 24 for receiving respective detected values P_N, P_B, P_A of the pressure sensors 21, 22, 23, processing them in a predetermined manner and then outputting an electric signal (current), and a proportional solenoid valve 25 operated by the electric signal from the controller 24. A control pressure output from the proportional solenoid valve 25 is input to the regulator 19.

[0031] The regulator 19 is made up of a hydraulic cylinder 2 for tilting the swash plate la, a servo valve 3 for horsepower control, and a servo valve 4 for flow rate control. A delivery pressure of the hydraulic pump 1 acts on one end of the servo valve 3 for horsepower control to thereby control the tilting amount of the swash plate so that the pump delivery pressure will not exceed a limit value. The control pressure output from the proportional solenoid valve 25 acts on one end of the servo valve 4 for flow rate control to thereby control the tilting amount of the swash plate so that the pump delivery rate depending on the control pressure is obtained.

[0032] Fig. 4 is a block diagram showing functions of the controller 24 shown in Fig. 1. The controller 24 includes a function generator 151 for calculating a target tilting amount (target displacement volume) θ_N corresponding to the detected value P_N of the negative control pressure from the pressure sensor 21, a function generator 152 for calculating a target tilting amount θ_B corresponding to the detected value P_B of the boom-up pilot pressure A from the pressure sensor 22, a function generator 153 for calculating a target tilting amount θ_A corresponding to the detected value P_A of the arm crowding pilot pressure E from the pressure sensor 23, a maximum value selector 154 for selecting larger one of the target tilting amounts θ_B and θ_A and outputting the selected one as a target tilting amount θ_O, a minimum value selector 155 for selecting smaller one of the target tilting amounts θ_N and θ_O and outputting the selected one as a target tilting amount θ, and a function generator 156 for calculating a current value I (a command value) corresponding to the target tilting amount θ. The current value I calculated by the function generator 156 is applied to a power supply unit (not shown) which in turn outputs an electric signal corresponding to the current value I to the proportional solenoid valve 25.

[0033] The function generator 151 has such a characteristic that it has a predetermined maximum value θ_{N1} and a predetermined minimum value θ_{N2}, and as the detected value P_N is reduced within a certain range of the detected value P_N, the tilting amount θ_N increases from the minimum value θ_{N2} to the maximum value θ_{N1} proportionally to the decrease in the detected value.

[0034] The function generator 152 has such a characteristic that it has a predetermined maximum value θ_{B1} and a predetermined minimum value θ_{B2}, and as the detected value P_B is increased within a certain range of the detected value P_B, the tilting amount θ_B increases from the minimum value θ_{B2} to the maximum value θ_{B1} proportionally to the increase in the detected value. Here, there hold relationships of $\theta_{B1} = \theta_{N1}$ and $\theta_{N2} < \theta_{B2} < \theta_{N1}$.

[0035] The function generator 153 has the same characteristic as that of the function generator 152, namely, its characteristic has a predetermined maximum value θ_{A1} (= θ_{B2}) and a predetermined minimum value θ_{A2} (= θ_{B2}), and as the detected value P_A is increased within a certain range of the detected value P_A, the tilting amount θ_A increases from the minimum value θ_{A2} to the maximum value θ_{A1} proportionally to the increase in the detected value.

[0036] In the above arrangement, the function generators 152, 153, the maximum value selector 154 and the minimum value selector 155 jointly make up maximum target displacement volume limiting means for limiting, depending on the detected value P_B or the detected val-

ue P_A of the pressure sensor 22 or 23, the maximum value of the target tilting amount θ_N calculated by the function generator 151 based on the detected value P_N of the pressure sensor 21, and providing the target tilting amount θ to be output.

[0037] The operation of the hydraulic pump control system of this embodiment will now be described. First, when any of the control levers 63e, 63e is not manipulated and all the flow control valves 10 to 13 are in the neutral positions, the center bypasses of the flow control valves are all fully opened and a hydraulic fluid delivered from the hydraulic pump 1 is passed at a full flow rate through the center bypass line 5. Therefore, the negative control pressure generated by the fixed throttle 20 is maximized and the detected value P_N of the pressure sensor 21 is also maximized. This maximum detected value P_N of the pressure sensor 21 is input to the function generator 151 in the controller 24 where the maximum value θ_{N1} is calculated as the target tilting amount θ_N.

[0038] Also, when all the flow control valves 10 to 13 are in the neutral positions, the pilot pressures A, E are not produced and the detected values $P_{B,}$, P_A of the pressure sensors 22, 23 are output as 0. The detected values $P_{B,}$, P_A are applied respectively to the function generators 152, 153 in the controller 24 where the minimum values θ_{B2}, θ_{A2} (= θ_{B2}) are calculated as the target tilting amounts θ_B, θ_A. Then, the maximum value selector 154 selects one of θ_{B2} and θ_{A2}, e.g., θ_{B2}, as the target tilting amount θ_O.

[0039] Since there holds the relationship of $\theta_{N2} < \theta_{B2} < \theta_{N1}$ as described above, the minimum value selector 155 selects θ_{N2} as the target tilting amount θ to be output and issues an electric signal corresponding to θ_{N2} to the proportional solenoid valve 25. Accordingly, the swash plate la of the hydraulic pump 1 is tilted to the minimum target tilting amount θ_{N2}, and the hydraulic pump 1 is kept at the minimum delivery rate.

[0040] Next, when the operator manipulates the control lever 62e solely over its full stroke in the direction of extending the boom cylinder 6, the flow control valve 10 is shifted to the left in Fig. 1 and the center bypass of the flow control valve 10 is restricted to reduce the flow rate passing through the center bypass line 15. The negative control pressure generated by the fixed throttle 20 and the detected value P_N of the pressure sensor 21 are reduced as the amount by which the control lever 62e is manipulated, i.e., the control input, increases. The detected value P_N of the pressure sensor 21 is applied to the function generator 151 in the controller 24, whereupon the target tilting amount θ_N calculated by the function generator 151 is changed from the minimum value θ_{N2} to the maximum value θ_{N1}.

[0041] Simultaneously, the pilot pressure A acting in the direction of extending the boom cylinder is detected by the pressure sensor 22 which outputs the detected value P_B. The detected value P_B is applied to the function generator 152 in the controller 24 where the calculated target tilting amount θ_B is increased as the control input from the control lever 62e increases, and the maximum target tilting amount θ_{B1} is finally calculated. In this case, because the control lever 63e is not manipulated in the direction of extending the arm cylinder 7, the target tilting amount θ_A calculated by the function generator 153 is the minimum value θ_{A2} (< θ_{B1}). Therefore, the maximum value selector 154 selects θ_{B1} as the target tilting amount θ_O.

[0042] Since there holds the relationship of $\theta_{B1} = \theta_{N1}$ as described above, the minimum value selector 155 selects one of θ_{B1} and θ_{N1}, e.g., θ_{N1}, as the target tilting amount θ to be output and issues an electric signal corresponding to θ_{N1} to the proportional solenoid valve 25. Accordingly, the swash plate la of the hydraulic pump 1 is tilted to the maximum target tilting amount θ_{N1} and the delivery rate of the hydraulic pump 1 is maximized, enabling the boom cylinder 6 to be driven at a sufficiently high speed.

[0043] Also, when the operator manipulates the control lever 63e solely over its full stroke in the direction of extending the arm cylinder 7, the swash plate la of the hydraulic pump 1 is tilted to the maximum target tilting amount θ_{N1} and the delivery rate of the hydraulic pump 1 is maximized in a like manner as described above, enabling the arm cylinder 7 to be driven at a sufficiently high speed.

[0044] When the operator manipulates the control lever 63e solely in the direction of driving the swing motor 9, the flow control valve 13 is shifted to the left, for example, in Fig. 1 and the center bypass of the flow control valve 13 is restricted to reduce the flow rate passing through the center bypass line 15. The negative control pressure generated by the fixed throttle 20 and the detected value P_N of the pressure sensor 21 are reduced as the amount by which the control lever 63e is manipulated, i.e., the control input, increases. The detected value P_N of the pressure sensor 21 is applied to the function generator 151 in the controller 24 where the target tilting amount θ_N increasing proportionally to the control input from the control lever 63e is calculated.

[0045] In this case, because neither the control lever 62e is manipulated in the direction of extending the boom cylinder 6, nor the control lever 63e is manipulated in the direction of extending the arm cylinder 7, the function generators 152, 153 calculate respectively the minimum values θ_{B2}, θ_{A2} ($\theta_{B2} = \theta_{A2}$) as the target tilting amounts θ_B, θ_A. Then, the maximum value selector 154 selects one of θ_{B2} and θ_{A2}, e.g., θ_{B2}, as the target tilting amount θ_O. Accordingly, when the target tilting amount θ_N calculated by the function generator 151 halfway the stroke of the control lever 63e is smaller than θ_{B2} ($\theta_N < \theta_{B2}$), the minimum value selector 155 selects θ_N as the target tilting amount θ. On the other hand, when the control input from the control lever 63e is increased to such an extent that the target tilting amount θ_N calculated by the function generator 151 increases to satisfy a relationship of $\theta_N > \theta_{B2}$, the minimum value selector 155

selects θ_{B2} as the target tilting amount θ. Stated otherwise, the minimum value selector 155 provides the target tilting amount θ to be output which is resulted by limiting, depending on the detected value P_B or P_A of the pressure sensor 22 or 23, the maximum value of the target tilting amount θ_N calculated by the function generator 151 based on the detected value P_N of the pressure sensor 21.

[0046] The swash plate la of the hydraulic pump 1 is tilted to the target tilting amount θ_N or θ_{B2} thus obtained from the minimum selector 155, and the delivery rate of the hydraulic pump 1 is controlled so as not to exceed the value corresponding to θ_{B2}. Consequently, even when the operator manipulates the control lever 63e over its full stroke in the direction of swinging the upper structure, the speed of the swing motor 9 is surely suppressed and prevented from exceeding the limit value.

[0047] Also, when the operator manipulates the control lever 62e solely in the direction of driving the bucket cylinder 8, the delivery rate of the hydraulic pump 1 is controlled so as not to exceed the value corresponding to θ_{B2} in a like manner as in the above case. Therefore, even when the operator manipulates the control lever 63e over its full stroke, the speed of the bucket cylinder 8 is surely suppressed and prevented from exceeding the limit value.

[0048] Next, when the operator manipulates simultaneously the control lever 62e in the direction of extending the boom ylinder 6 and the control lever 63e in the direction of driving the swing motor 9, the negative control pressure and the pilot pressure for operating the boom are generated, whereupon the function generators 151, 152 calculate respectively the tilting amounts θ_N, θ_B corresponding to the detected values P_N, P_B of the pressure sensors 21, 22. In this case, with the control lever 62e manipulated over its full stroke in the direction of extending the boom cylinder 6, the function generators 151, 152 finally calculate the same maximum target tilting amount θ_{N1} (= θ_{B1}). Then, the maximum value selector 154 selects θ_{B1} as the target tilting amount θ_O, and the minimum value selector 155 selects one of θ_{N1} and θ_{B1}, e.g., θ_{N1}, as the target tilting amount θ. Correspondingly, the swash plate la is controlled so as to have the maximum tilting amount. At this time, while the delivery rate of the hydraulic pump 1 is maximized, this maximum delivery rate is distributed to both the boom cylinder 6 and the swing motor 9, and hence the swing motor 9 is prevented from operating at an excessive speed.

[0049] Also, when the operator manipulates simultaneously the control lever 63e in the direction of extending the arm cylinder 7 and the control lever 62e in the direction of driving the bucket cylinder 8, the delivery rate of the hydraulic pump 1 is maximized in a like manner as in the above case, but this maximum delivery rate is distributed to both the arm cylinder 7 and the bucket cylinder 8, and hence the bucket cylinder 8 is prevented from operating at an excessive speed.

[0050] With this embodiment, therefore, the swing motor 9 and the bucket cylinder 8 which are each desired to have a small maximum driving speed can be surely suppressed in speed. It is thus possible to avoid inaccuracy in the stopped position of the swing motor 9, deterioration in durability of the swing motor itself and speed reducing gears, undue noise, etc. which would be otherwise caused by the excessive speed of the swing motor 9. Also, it is possible to avoid shocks, useless pressure relief, deterioration in durability of the bucket cylinder 8, etc. which would be otherwise caused by the bucket cylinder striking against the stroke end. Further, since the function generators 152, 153 have characteristics changing continuously, the delivery rate of the hydraulic pump varies smoothly and the hydraulic actuators are prevented from abruptly changing in speed.

[0051] A second embodiment of the present invention will be described below with reference to Figs. 6. In operation of hydraulic excavators, it is demanded to drive the arm 105 at a low speed when the arm is horizontally pushed forward for the leveling work. This embodiment is intended to add a function to meet such a demand. In the figures, identical members and functions to those in Figs. 1 and 4 are denoted by the same reference numerals.

[0052] In Fig. 6, the hydraulic pump control system of this embodiment comprises, in addition to the components of the above--described system of the first embodiment, a pressure sensor 30 for detecting the pilot pressure F that acts on the arm dumping side of the flow control valve 11, and a selection switch 31 to be depressed by the operator when carrying out the leveling work. A controller 24A receives, in addition to the detected values P_N, P_B, P_A of the pressure sensors 21, 22, 23, a detected value P_{AD} of the pressure sensor 30 and a selection signal S from the selection switch 31, processing them in a predetermined manner and then outputting an electric signal (current) to the proportional solenoid valve 25.

[0053] As seen from Fig. 7, the controller 24A includes, in addition to the functions shown in Fig. 4 for the controller of the first embodiment, a function generator 157 for calculating a target tilting amount θ_{AD} corresponding to the detected value P_{AD} of the arm dumping pilot pressure F from the pressure sensor 30, and a selector 158 for inhibiting the target tilting amount θ_{AD} calculated by the function generator 157 from being output when the selection switch 31 is not depressed and the selection signal S is turned off, and allowing the target tilting amount θ_{AD} calculated by the function generator 157 to be output when the selection switch 31 is depressed and the selection signal S is turned on. The target tilting amount θ_{AD} output from the selector 158 is sent to the minimum value selector 155.

[0054] As shown, the function generator 157 has such a characteristic that it has a predetermined maximum value θ_{AD1} and a predetermined minimum value θ_{AD2},

and as the detected value P_{AD} is increased within a certain range of the detected value P_B, the tilting amount θ_{AD} reduces from the maximum value θ_{AD1} to the minimum value θ_{AD2} proportionally to the increase in the detected value. Here, there hold relationships of $\theta_{AD1} = \theta_{N1}$ and $\theta_{N2} < \theta_{AD2} < \theta_{N1}$.

[0055] When the selection switch 31 is not depressed in the above arrangement, the target tilting amount θ_{AD} calculated by the function generator 157 is not output from the selector 158 and the system operates in a like manner as in the first embodiment.

[0056] When the selection switch 31 is depressed, the target tilting amount θ_{AD} calculated by the function generator 157 is output from the selector 158 to the minimum value selector 155. Therefore, even when the operator manipulates the control lever 63e to a large extent in the direction of contracting the arm cylinder 7 for pushing the arm forward horizontally with intent to carry out the leveling work by the combined operation of boom-up or boom-down and arm dumping of the hydraulic excavator, the function generator 157 calculates the minimum value θ_{AD2} ($< \theta_{N1}$) or a value thereabout as the target tilting amount θ_{AD}. The minimum value selector 155 selects the minimum target tilting amount θ_{AD2} or the value thereabout as the target tilting amount θ and outputs an electric signal corresponding to θ_{AD2} or the value thereabout to the proportional solenoid valve 25. Accordingly, the swash plate la of the hydraulic pump 1 is tilted to θ_{AD2} or the value thereabout, and the delivery rate of the hydraulic pump 1 is controlled to a small value corresponding to θ_{AD2} or the value thereabout. As a result, the arm dumping speed is slowed to such an extent that the arm can be horizontally pushed forward with good fine operability.

[0057] When the operator manipulates the control lever 62e over its full stroke with intent to move up the boom solely, the function generator 151 calculates the maximum value θ_{N1} as the target tilting amount and the function generator 152 calculates the maximum value θ_{B1} ($= \theta_{N1}$) as with the first embodiment described above. On the other hand, since the control lever 63e is not manipulated in the direction of contracting the arm cylinder 7, the function generator 157 calculates the maximum value θ_{AD1} ($= \theta_{N1}$). Eventually, the minimum selector 155 selects the maximum value θ_{N1} as the target tilting amount. Therefore, the boom cylinder 6 can be driven at a high speed to quickly move up the boom without being restricted by the target tilting amount θ_{AD} calculated by the function generator 157.

[0058] While the above embodiments have been described in connection with the swing motor, the boom cylinder, the arm cylinder and the bucket cylinder of the hydraulic excavator, the present invention is also applicable to a track motor which is desired to have a large maximum driving speed. The present invention can be further applied to hydraulic actuators of working machines other than hydraulic excavators. While the above embodiments have been described as detecting the control inputs from the control levers through the pilot pressures, the control inputs may be detected in an electrical manner. The regulator may be of any type so long as it is operated in such a manner as able to precisely represent the target tilting amount obtained by the controller. In addition, it is apparent that the function generators, the maximum value selector and the minimum value selector can be constituted by using a microcomputer.

INDUSTRIAL APPLICABILITY

[0059] According to the present invention, as described above, it is possible to surely prevent an unwanted speed increase of a specific hydraulic actuator that would be caused when tilting amount control is carried out by using only the negative control pressure.

Claims

1. A hydraulic pump control system for use with a hydraulic drive system comprising a variable displacement hydraulic pump (1), a plurality of hydraulic actuators (6-9) driven by said hydraulic pump, a plurality of flow control valves (10-13) of the center bypass type for controlling the driving of said hydraulic actuators, (6-9) and a center bypass line (5) connecting the center bypasses of said flow control valves (10-13) in series, said hydraulic pump control system controlling a displacement volume of said hydraulic pump by using a negative control pressure generated by flow resisting means (20) which is disposed downstream of said center bypass line, said hydraulic pump control system comprising

   pressure detecting means (21) for detecting the negative control pressure generated in said center bypass line (5),
   first target displacement volume calculating means (151) for calculating, based on a detected value of said pressure detecting means, a first target displacement volume of said hydraulic pump (1) in accordance with a preset first characteristic,
   first control input detecting means (22 or 23) for detecting a control input for operating at least one (6 or 7) of said plurality of hydraulic actuators, (6-9),
   maximum target displacement volume limiting means (152-155) for limiting, depending on the detected value of said first control input detecting means (22,23), a maximum value of the first target displacement volume calculated by said first target displacement volume calculating means (152-155) based on the detected value of said pressure detecting means (21), and pro-

viding a target displacement volume to be output, and

a regulator (26) for controlling the displacement volume of said hydraulic pump in accordance with said target displacement volume to be output.

2. A hydraulic pump control system according to Claim 1, wherein said maximum target displacement volume limiting means comprises second target displacement volume calculating means (152 or 153) for calculating, based on the detected value of said first control input detecting means (22 or 23), a second target displacement volume of said hydraulic pump (1) in accordance with a preset second characteristic different from said first characteristic, and smaller value selecting means (155) for selecting smaller one of said first and second target displacement volumes as said target displacement volume to be output.

3. A hydraulic pump control system according to Claim 2, wherein said first characteristic is such that said first target displacement volume increases from a predetermined minimum value (θ_{N2}) to a predetermined maximum value (θ_{N1}) as the detected value of said pressure detecting means (21) is reduced, and said second characteristic is such that said second target displacement volume increases from a predetermined minimum value (θ_{B2} or θ_{A2}) to a predetermined maximum value (θ_{B1} or θ_{A1}) as the detected value of said first control input detecting means (22 or 23) is increased, the predetermined minimum value (θ_{B2} or θ_{A2}) of said second characteristic being smaller than the predetermined maximum value (θ_{N1}) of said first characteristic.

4. A hydraulic pump control system according to Claim 3, wherein the predetermined maximum value (θ_{B1} or θ_{A1}) of said second characteristic is equal to the predetermined maximum value (θ_{N1}) of said first characteristic.

5. A hydraulic pump control system according to Claim 2, further comprising second control input detecting means (30) for detecting a control input for operating other one (7) of said plurality of hydraulic actuators or a control input in a different direction from the control input for operating said at least one hydraulic actuator (7), wherein said maximum target displacement volume limiting means further comprises third target displacement volume calculating means (157) for calculating, based on the detected value of said second control input detecting means, a third target displacement volume of said hydraulic pump (1) in accordance with a preset third characteristic different from both said first and second characteristics, and said smaller value selecting means (155) selects a minimum value of said first, second and third target displacement volumes as said target displacement volume to be output.

6. A hydraulic pump control system according to Claim 5, wherein said third characteristic is such that said third target displacement volume reduces from a predetermined maximum value (θ_{AD1}) to a predetermined minimum value (θ_{AD2}) as the detected value of said second control input detecting means is increased.

7. A hydraulic pump control system according to Claim 1, wherein said at least one actuator is an actuator (6 or 7) of which desired maximum driving speed is relatively large.

8. A hydraulic pump control system according to Claim 7, wherein said actuator of which desired maximum driving speed is relatively large is a boom cylinder (6) for operating a boom (104) of a hydraulic excavator.

9. A hydraulic pump control system according to Claim 7, wherein said actuator of which desired maximum driving speed is relatively large is an arm cylinder (7) for operating an arm (105) of a hydraulic excavator.

Patentansprüche

1. Hydraulikpumpen-Steuersystem, das in Verbindung mit einem Hydraulikantriebssystem verwendet wird, das eine Hydraulikpumpe (1) mit variabler Verdrängung, mehrere Hydraulikaktuatoren (6-9), die durch die Hydraulikpumpe angetrieben werden, mehrere Durchflußmengensteuerventile (10-13) des Mittenumgehungstyps zur Steuerung des Antriebs der Hydraulikaktuatoren (6-9) und eine Mittenumgehungsleitung (5), die die Mittenumgehungen der Durchflußmengensteuerventile (10-13) in Reihe verbindet, umfaßt, wobei das Hydraulikpumpen-Steuersystem das Verdrängungsvolumen der Hydraulikpumpe unter Verwendung eines Steuerunterdrucks steuert, der durch eine Strömungswiderstandseinrichtung (20) erzeugt wird, die stromabwärts von der Mittenumgehungsleitung angeordnet ist, wobei das Hydraulikpumpen-Steuersystem umfaßt:

eine Druckerfassungseinrichtung (21), die den Steuerunterdruck, der in der Mittenumgehungsleitung (5) erzeugt wird, erfaßt,

eine Einrichtung (151) zur Berechnung eines ersten Sollverdrängungsvolumens, die auf der Grundlage eines erfaßten Wertes der Druckerfassungseinrichtung ein erstes Sollverdrän-

gungsvolumen der Hydraulikpumpe (1) in Übereinstimmung mit einer im voraus festgelegten ersten Charakteristik berechnet,
eine Einrichtung (22 oder 23) zur Erfassung eines ersten Steuereingangs, die einen Steuereingang zum Betreiben wenigstens eines (6 oder 7) der mehreren Hydraulikaktuatoren (6-9) erfaßt,
eine Einrichtung (152-155) zur Begrenzung des maximalen Sollverdrängungsvolumens, die in Abhängigkeit von dem erfaßten Wert der Einrichtung (22, 23) zur Erfassung eines ersten Steuereingangs einen Maximalwert des ersten Sollverdrängungsvolumens, das durch die Einrichtung (152-155) zur Berechnung eines ersten Sollverdrängungsvolumens auf der Grundlage des erfaßten Wertes der Druckerfassungseinrichtung (21) berechnet wird, begrenzt und ein auszugebendes Sollverdrängungsvolumen bereitstellt, und
einen Regler (26), der das Verdrängungsvolumen der Hydraulikpumpe in Übereinstimmung mit dem auszugebenden Sollverdrängungsvolumen steuert.

2. Hydraulikpumpen-Steuersystem nach Anspruch 1, wobei die Einrichtung zur Begrenzung des maximalen Sollverdrängungsvolumens eine Einrichtung (152 oder 153) zur Berechnung eines zweiten Sollverdrängungsvolumens, die auf der Grundlage des erfaßten Wertes der Einrichtung (22 oder 23) zur Erfassung eines ersten Steuereingangs ein zweites Sollverdrängungsvolumen der Hydraulikpumpe (1) in Übereinstimmung mit einer von der ersten Charakteristik verschiedenen und im voraus festgelegten zweiten Charakteristik berechnet, sowie eine Einrichtung (155) zum Wählen eines kleineren Werts, die das kleinere der ersten und zweiten Sollverdrängungsvolumina als auszugebendes Sollverdrängungsvolumen wählt, umfaßt.

3. Hydraulikpumpen-Steuersystem nach Anspruch 2, wobei die erste Charakteristik derart ist, daß das erste Sollverdrängungsvolumen ausgehend von einem vorgegebenen Minimalwert (θ_{N2}) auf einen vorgegebenen Maximalwert (θ_{N1}) ansteigt, wenn der erfaßte Wert der Druckerfassungseinrichtung (21) verringert wird, und die zweite Charakteristik derart ist, daß das zweite Sollverdrängungsvolumen ausgehend von einem vorgegebenen Minimalwert (θ_{B2} oder θ_{A2}) auf einen vorgegebenen Maximalwert (θ_{B1} oder θ_{A1}) ansteigt, wenn der erfaßte Wert der Einrichtung (22 oder 23) zur Erfassung eines ersten Steuereingangs erhöht wird, wobei der vorgegebene Minimalwert (θ_{B2} oder θ_{A2}) der zweiten Charakteristik kleiner als der vorgegebene Maximalwert (θ_{N1}) der ersten Charakteristik ist.

4. Hydraulikpumpen-Steuersystem nach Anspruch 3, wobei der vorgegebene Maximalwert (θ_{B1} oder θ_{A1}) der zweiten Charakteristik gleich dem vorgegebenen Maximalwert (θ_{N1}) der ersten Charakteristik ist.

5. Hydraulikpumpen-Steuersystem nach Anspruch 2, ferner mit einer Einrichtung (30) zur Erfassung eines zweiten Steuereingangs, die einen Steuereingang zum Betreiben eines weiteren (7) der mehreren Hydraulikaktuatoren oder einen Steuereingang in einer vom Steuereingang zum Betreiben des wenigstens einen Hydraulikaktuators (7) verschiedenen Richtung erfaßt, wobei die Einrichtung zur Begrenzung des maximalen Sollverdrängungsvolumens ferner eine Einrichtung (157) zur Berechnung eines dritten Sollverdrängungsvolumens umfaßt, die auf der Grundlage des erfaßten Wertes der Einrichtung zur Erfassung eines zweiten Steuereingangs ein drittes Sollverdrängungsvolumen der Hydraulikpumpe (1) in Übereinstimmung mit einer im voraus festgelegten dritten Charakteristik, die sowohl von der ersten als auch von der zweiten Charakteristik verschieden ist, berechnet, und wobei die Einrichtung (155) für die Wahl eines kleineren Wertes den kleinsten Wert der ersten, zweiten und dritten Sollverdrängungsvolumina als das auszugebende Sollverdrängungsvolumen wählt.

6. Hydraulikpumpen-Steuersystem nach Anspruch 5, wobei die dritte Charakteristik derart ist, daß das dritte Sollverdrängungsvolumen ausgehend von einem vorgegebenen Maximalwert (θ_{AD1}) auf einen vorgegebenen Minimalwert (θ_{AD2}) abnimmt, wenn der erfaßte Wert der zweiten Einrichtung zur Erfassung eines Steuereingangs ansteigt.

7. Hydraulikpumpen-Steuersystem nach Anspruch 1, wobei der wenigstens eine Aktuator ein Aktuator (6 oder 7) ist, dessen erwünschte maximale Antriebsgeschwindigkeit verhältnismäßig hoch ist.

8. Hydraulikpumpen-Steuersystem nach Anspruch 7, wobei der Aktuator, dessen gewünschte maximale Antriebsgeschwindigkeit verhältnismäßig hoch ist, ein Auslegerzylinder (6) ist, der einen Ausleger (104) eines Hydraulikbaggers betätigt.

9. Hydraulikpumpen-Steuersystem nach Anspruch 7, wobei der Aktuator, dessen erwünschte maximale Antriebsgeschwindigkeit verhältnismäßig hoch ist, ein Armzylinder (7) ist, der einen Arm (105) eines Hydraulikbaggers betätigt.

Revendications

1. Un système de commande de pompe hydraulique, pour utilisation avec un système de pompe d'entraî-

nement hydraulique, comprenant une pompe hydraulique (1) à cylindrée variable, une pluralité d'actionneurs hydrauliques (6 à 9) entraînés par ladite pompe hydraulique, une pluralité de valves de commande de débit (10 à 13) du type à dérivation centrale, pour commander l'entraînement desdits actionneurs hydrauliques (6 à 9), et une ligne de dérivation centrale (5) connectant en série les dérivations centrales desdites soupapes de débit (10 à 13), ledit système de pompe hydraulique commandant le débit-volume de ladite pompe hydraulique, par utilisation d'une pression de commande négative générée par des moyens de résistance à l'écoulement (20) placés en aval de ladite tuyauterie de dérivation centrale, ledit système de commande de pompe hydraulique comprenant :

- des moyens de détection de pression (21), pour appréhender la pression de commande négative dans ladite ligne de dérivation centrale (5) ;
- des premiers moyens de calcul de débit-volume de consigne (151), pour calculer, en se basant sur une valeur appréhendée par lesdits moyens de détection de pression, un premier volume de refoulement de consigne de ladite pompe hydraulique (1), selon une première caractéristique pré-établie ;
- des premiers moyens de détection d'entrée de commande (22 ou 23), pour détecter une entrée de commande pour actionner au moins l'un (6 ou 7) parmi ladite pluralité d'actionneurs hydrauliques (6 à 9) ;
- des moyens de limitation de débit-volume de consigne maximum (152 à 155) destinés à limiter, selon la valeur détectée desdits premiers moyens de détection d'entrée de commande (22, 23), une valeur maximale du premier débit-volume de consigne, calculée par lesdits premiers moyens de calcul de débit-volume de consigne (152 à 155), en se basant sur la valeur détectée desdits moyens de détection de pression (21), et à fournir un débit-volume de consigne devant être produit, et
- un régulateur (26) pour commander le débit-volume de ladite pompe hydraulique, d'après le débit-volume de consigne à fournir.

2. Un système de commande de pompe hydraulique selon la revendication 1, dans lequel ledit moyen de limitation de débit-volume de consigne maximal comprend des deuxièmes moyens de calculs de débit-volume de consigne (152 ou 153), pour calculer, en se basant sur la valeur détectée desdits premiers moyens de détection d'entrée de commande (22 ou 23), un deuxième débit-volume de consigne de ladite pompe hydraulique (1), selon une deuxième caractéristique pré-établie, différente de ladite première caractéristique, et des moyens de sélection de valeur inférieure (155) pour sélectionner parmi lesdits premier et deuxième débits- volume de consigne, à titre de débit-volume de consigne à produire, celui qui est le plus petit.

3. Un système de commande de pompe hydraulique selon la revendication 2, dans lequel ladite première caractéristique est telle que ledit premier débit-volume de consigne augmente, depuis une valeur minimale prédéterminée (θ_{N2}) à une deuxième valeur prédéterminée (θ_{N1}), lorsque la valeur détectée desdits moyens de détection de pression (21) est réduite, et ladite caractéristique est telle que ledit deuxième débit-volume de consigne augmente, depuis une valeur minimale pré-déterminée (θ_{B2} ou θ_{A2}) à une valeur maximale prédéterminée (θ_{B1} ou θ_{A1}), lorsque la valeur détectée desdits premiers moyens de détection d'entrée de commande (22 ou 23) est augmentée, la valeur minimale prédéterminée (θ_{B2} ou θ_{A2}) de ladite deuxième caractéristique étant inférieure à la valeur maximale prédéterminée (θ_{N1}) de ladite première caractéristique.

4. Un système de commande de pompe hydraulique selon la revendication 3, dans lequel la valeur maximale prédéterminée (θ_{B1} ou θ_{A1}) de ladite deuxième caractéristique est égale à la valeur maximale prédéterminée (θ_{N1}) de ladite première caractéristique.

5. Un système de commande de pompe hydraulique selon la revendication 2, comprenant en outre des deuxièmes moyens de détection d'entrée de commande (30), pour détecter une entrée de commande pour actionner l'autre (7) de ladite pluralité d'actionneurs hydrauliques ou une entrée de commande dans un sens différent de l'entrée de commande prévue pour actionner ledit au moins un actionneur hydraulique (7), dans lequel ledit moyen de limitation de débit-volume de consigne maximal comprend en outre des troisièmes moyens de calculs de débit-volume de consigne (157), pour calculer, en se basant sur la valeur détectée desdits deuxièmes moyens de détection d'entrée de commande, un troisième débit-volume de consigne de ladite pompe hydraulique (1), en fonction d'une troisième caractéristique pré-établie, différente desdites deux première et deuxième caractéristiques, et lesdits moyens de sélection de valeur inférieure (155) sélectionnant une valeur minimale parmi lesdits premier, deuxième et troisième débits-volumes de consigne, à titre de débit-volume de consigne à produire.

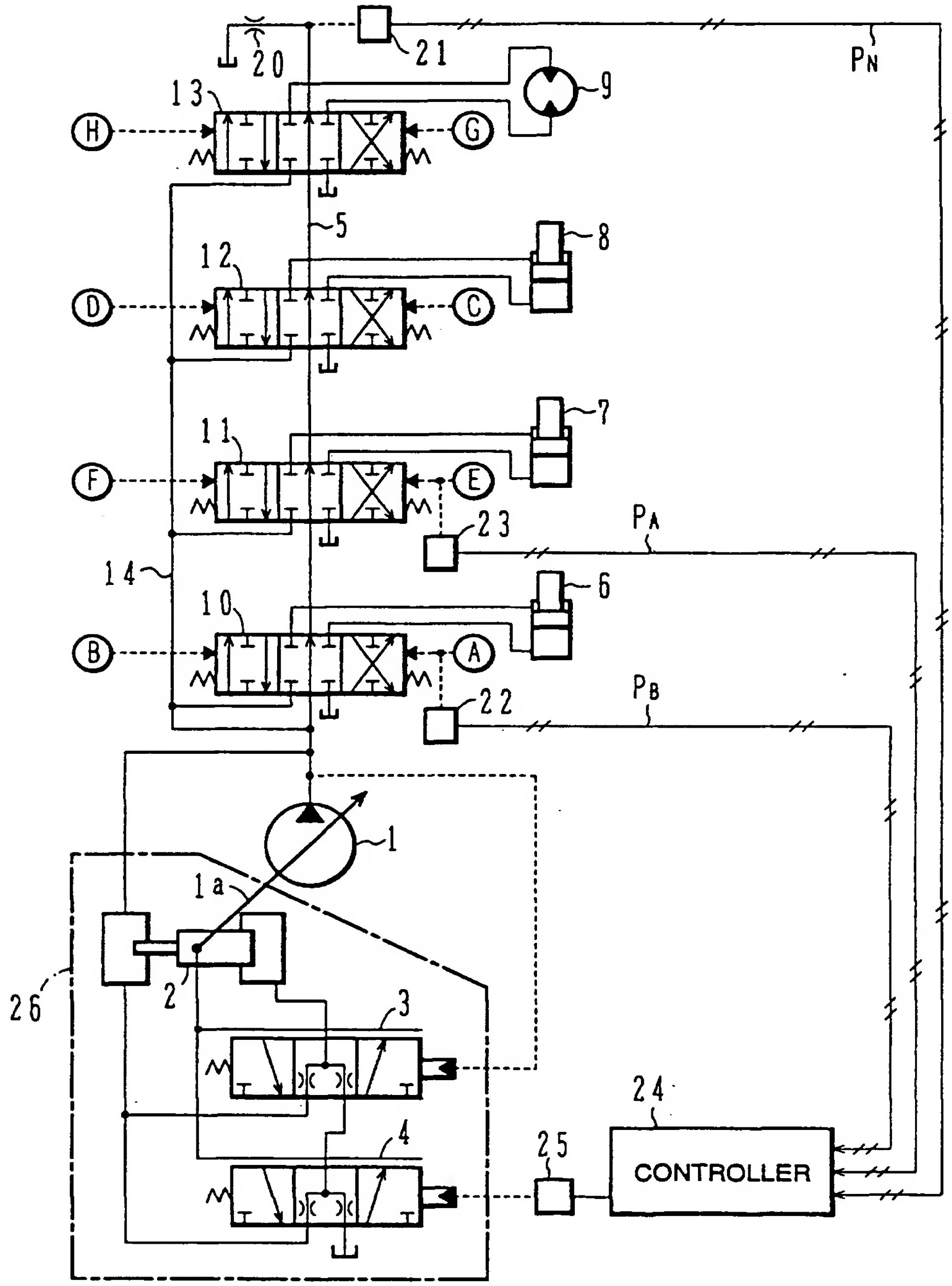
6. Un système de commande de pompe hydraulique selon la revendication 5, dans lequel ladite troisième caractéristique est telle que ledit troisième débit-volume de consigne diminue depuis une valeur maximale prédéterminée (θ_{AD1}) à une valeur minimale prédéterminée (θA_{D2}) lorsque la valeur détectée par lesdits deuxièmes moyens de détection d'entrée de commande augmente.

7. Un système de commande de pompe hydraulique selon la revendication 1, dans lequel au moins un actionneur est un actionneur (6 ou 7) dont la vitesse d'entraînement maximale souhaitée est relativement élevée.

8. Un système de commande de pompe hydraulique selon la revendication 7, dans lequel ledit actionneur, dont la vitesse maximale d'entraînement souhaitée est relativement élevée, est un cylindre de vérin de flèche (6), pour actionner une flèche (104) d'une excavatrice hydraulique.

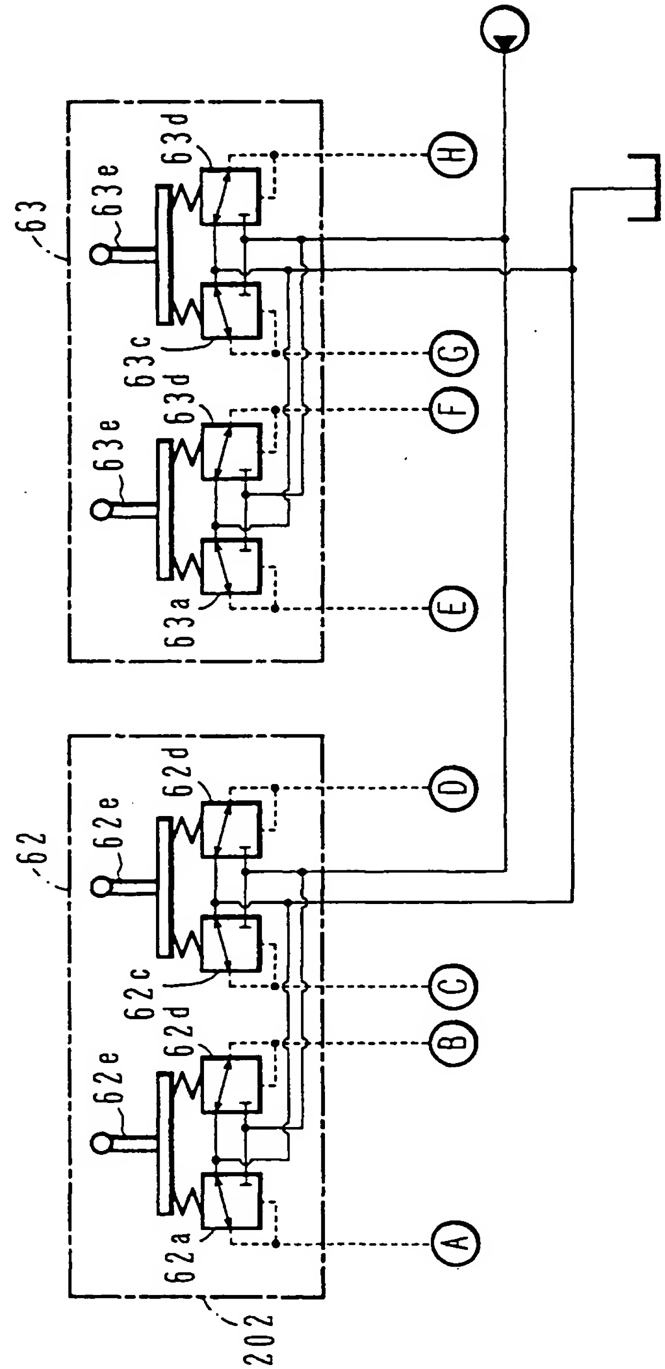
9. Un système de commande de pompe hydraulique selon la revendication 7, dans lequel ledit actionneur, dont la vitesse maximale d'entraînement souhaitée est relativement élevée, est un cylindre de vérin de bras (7) pour actionner un bras (105) d'une excavatrice hydraulique.

FIG.1



20
21
PN
13
9
H
G
5
12
8
D
C
11
7
F
E
23
PA
14
10
6
B
A
22
PB
1
1a
26
2
3
24
25
CONTROLLER
4

FIG.2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63d
63a
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202
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C
D
E
F
G
H

FIG.3

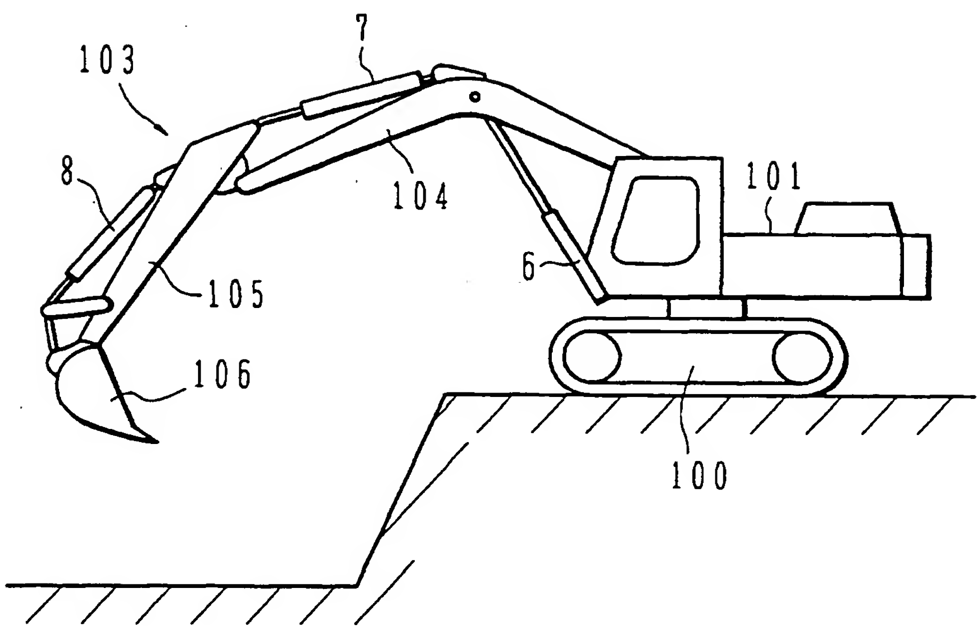


FIG.4

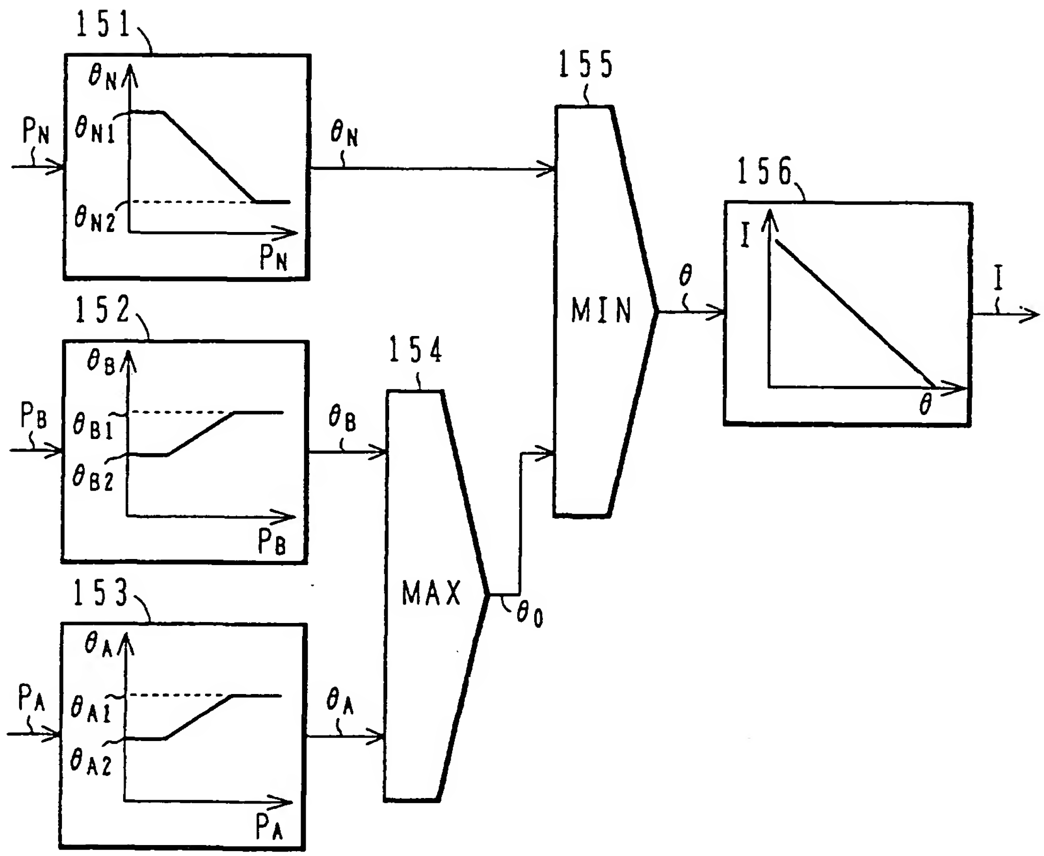

151
θ_N
P_N
θ_{N1}
θ_{N2}
P_N
θ_N
152
θ_B
P_B
θ_{B1}
θ_{B2}
P_B
θ_B
153
θ_A
P_A
θ_{A1}
θ_{A2}
P_A
θ_A
154
MAX
θ_0
155
MIN
θ
156
I
θ
I

FIG.5

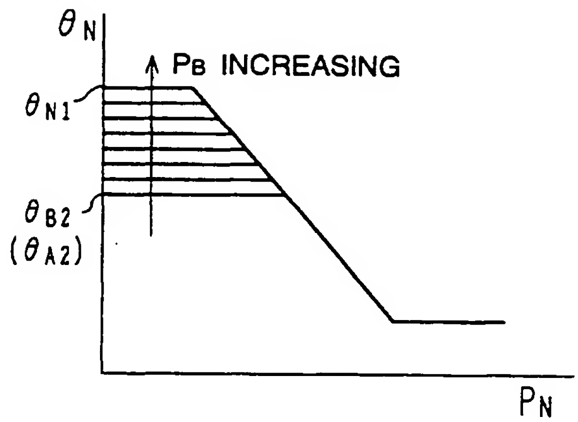
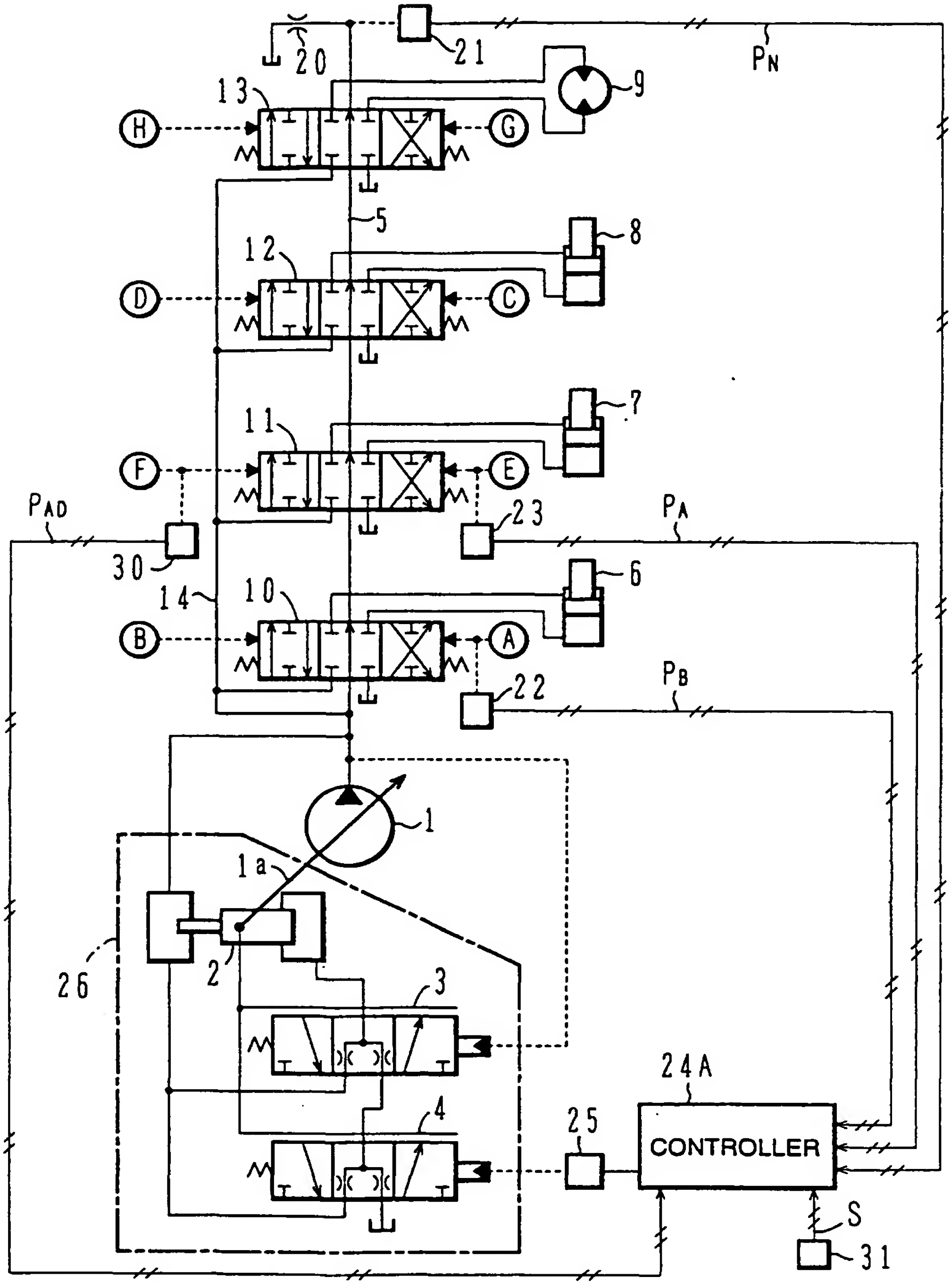
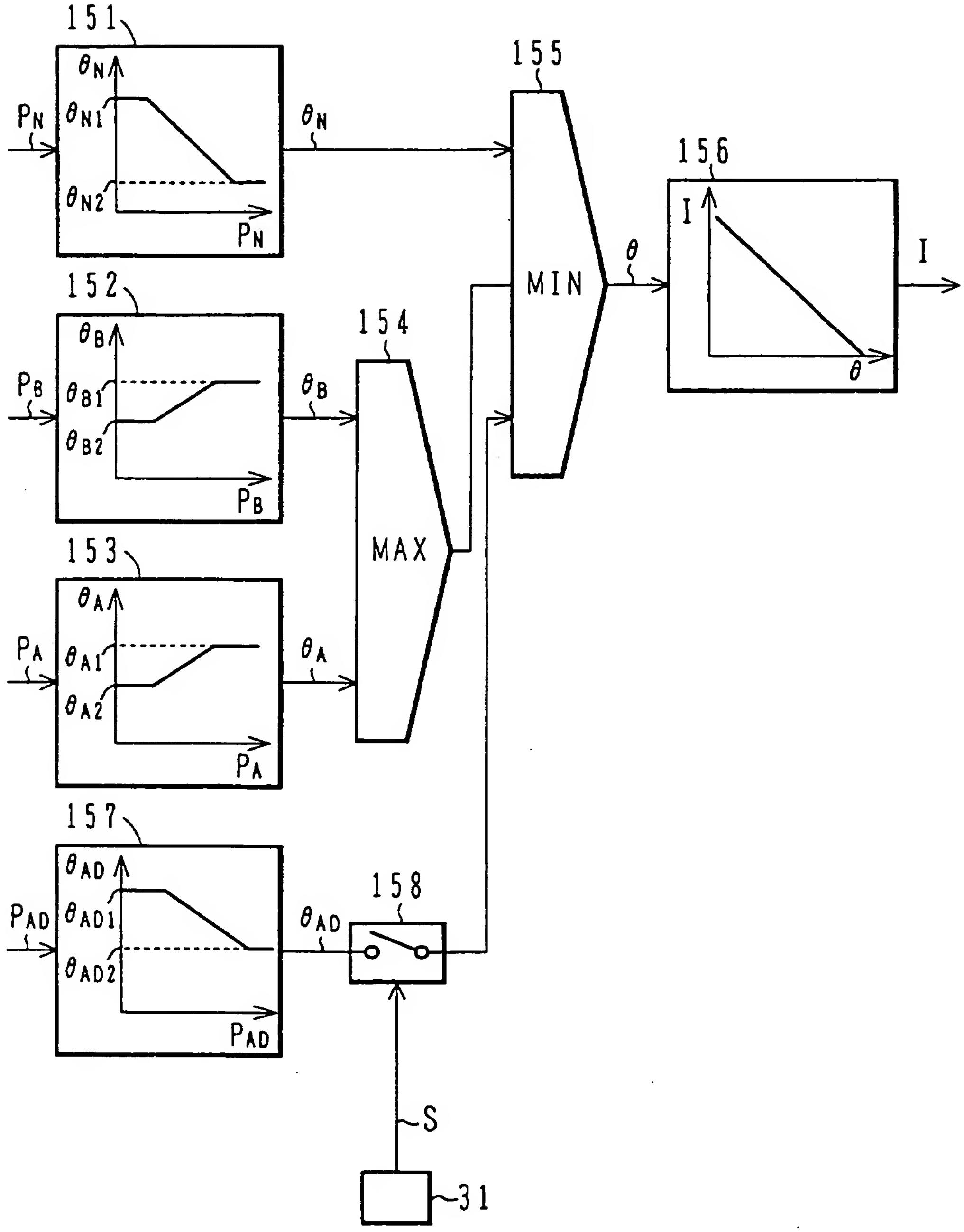


FIG.6



20
21
P_N
9
13
H
G
5
12
8
D
C
11
7
F
E
P_{AD}
30
23
P_A
14
10
6
B
A
22
P_B
1
1a
26
2
3
24A
25
CONTROLLER
4
S
31

FIG.7


151
θN
θN1
θN2
PN
θN
152
θB
θB1
θB2
PB
θB
153
θA
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PA
θA
157
θAD
θAD1
θAD2
PAD
θAD
154
MAX
155
MIN
θ
156
I
I
158
S
31